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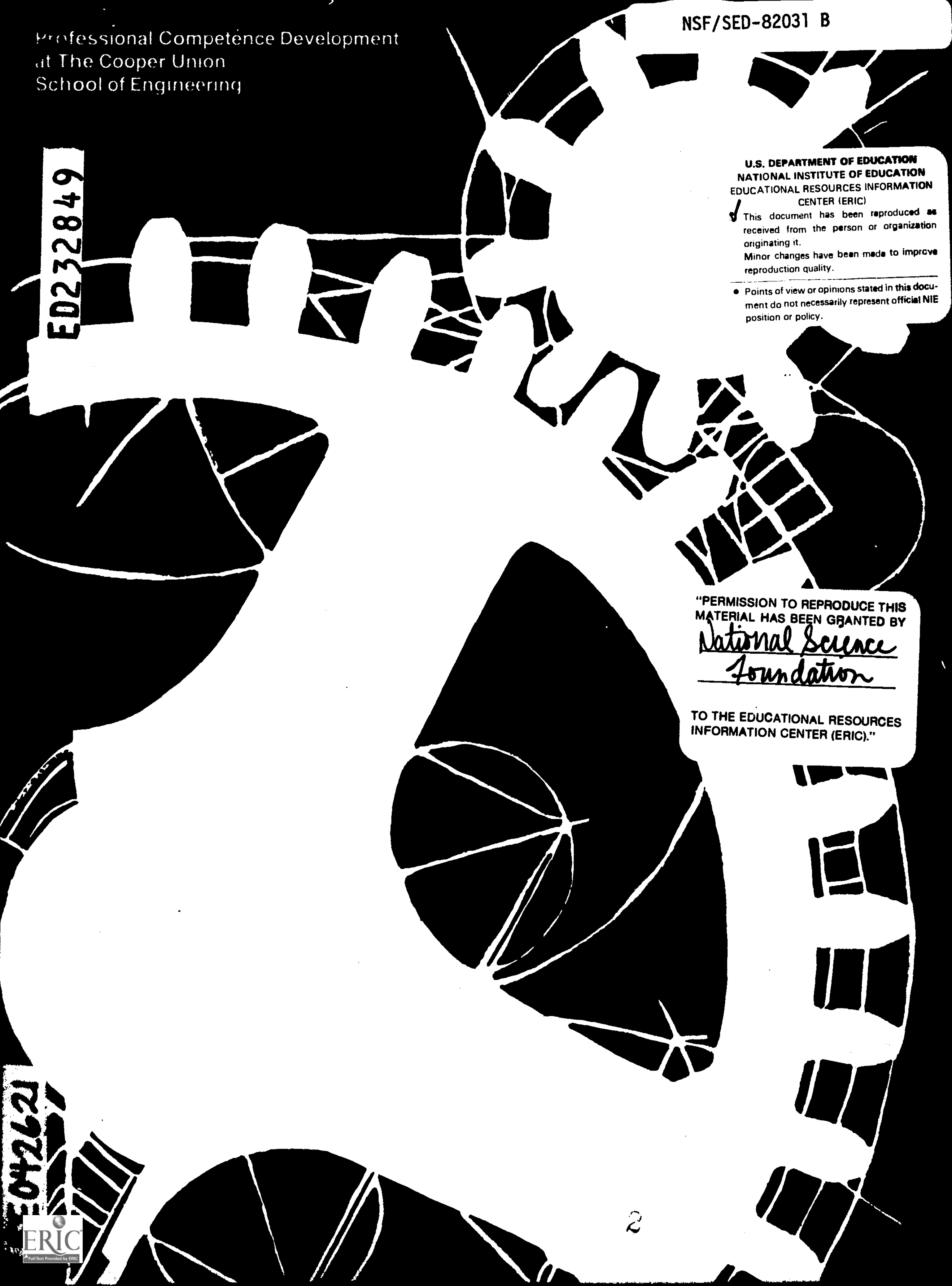
ABSTRACT

A 3-year project was developed to increase students' abilities to perform competently as professional engineers. The project sought to infuse into existing courses concern for, practice with, and development of three competencies critical to professional success: problem-solving, communication, and value clarification. Eight elementary and advanced courses, representing about a sixth of a student's total courses were modified over the 3-year period and were taught to one or more of three successive classes of students recruited for the project. These courses included: Basic Humanities; Introduction to Politics; Mechanics; Introductory Physics Laboratory; Environmental Fundamentals; Analytic Geometry, Vectors and Matrices, and Calculus; Engineering Design and Problem Solving; and Linear Systems. This publication reports on the design and implementation of the project and the analysis of results. Included in the design/implementation section are: discussions of the three competencies and levels of proficiency, faculty training, course development, participants, and evaluation methods; a list of questions for observation and analysis during the course of the project; and a chronology of key project events. The questions are used as a framework for discussing project results. Included in the appendices are: key features of course modifications; sample excerpts from class assignments, study guides, and assignment manuals; and a student course evaluation form. (JN)

Professional Competence Development
at The Cooper Union
School of Engineering



School of Engineering
The Cooper Union for the Advancement of Science and Art
41 Cooper Square
New York, NY 10003

December 1982

The Cooper Union for the Advancement of Science and Art, established in 1859, is a private, tuition-free institution of higher learning. Peter Cooper's legacy supports the School of Art, the School of Architecture, and the School of Engineering, all of which grant degrees; the Faculty of Liberal Arts and Sciences, and the Division of Adult Education, which administers the historic Cooper Union Forum. The Cooper Union is located at Cooper Square, New York, NY 10003.

This report prepared in collaboration with Educational Facilities Laboratories, a division of the Academy for Educational Development, New York, NY. Ellen Bussard is the primary author.

ABSTRACT

The Cooper Union School of Engineering recently completed a three-year project, funded by the National Science Foundation, to increase students' abilities to perform competently as professional engineers.

The project sought to infuse into existing courses concern for, practice with, and development of three competences critical to professional success: problem-solving, communication, and values clarification. Eight elementary and advanced courses, representing about a sixth of a student's total courses at The Cooper Union, were modified over the three-year period and were taught to one or more of three successive classes of students recruited for the project.

This publication reports on the design and implementation of the project and analysis of results.

ACKNOWLEDGEMENTS

This project has spanned three years from September 1979 to September 1982. It has been supported externally by the National Science Foundation and internally by a dedicated group of participants who have devoted to it much of their energies during that time. Their willingness to innovate and to try the untried in the face of many challenges is very much appreciated. Much help, encouragement, support and advice has been received from the Project Advisory Board and the consultants. May they be thanked formally here.

We wish also to record a debt of gratitude to Dr. G. d'Amour of the NSF who provided guidance in the early stages of this project.

J. LeMée
Project Director

PROFESSIONAL COMPETENCE DEVELOPMENT AT THE COOPER UNION SCHOOL OF ENGINEERING

PROJECT REPORT

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INTRODUCTION

Professional engineering schools educate competent engineering professionals, right?

Not often enough, not well enough, and not consciously enough, concluded a group of faculty members at The Cooper Union's School of Engineering four years ago. After reviewing the school's curriculum and the needs of professional practice, Cooper's faculty group called for the school to spend more time cultivating the professional competences of its students as well as the academic engineering subject content it teaches so well.

The faculty review group suggested a pilot project to modify existing courses so that the "hidden curriculum" of professional skills could be taught openly and emphatically. These professional skills include the ability to work from fundamental principles, to innovate, to relate problems to a wider context of space, time and values, to take responsibilities as team leaders and to work on realistic, if not always real, problems; to learn independently; to communicate effectively in writing and verbally; and to be reliable, thorough, productive and confident.

With funding from the National Science Foundation's program of Development in Science Education (DISE), The Cooper Union embarked on the pilot project from 1980 to 1982. Eight courses in the existing curriculum were modified to include systematic attention to three selected competences: problem-solving, communication, and values-clarification.

This publication is a report of the competence project at The Cooper Union: how it was designed and implemented, what lessons were learned, and what suggestions can be made to other institutions interested in improving professional competence development. It is one of three reports on The Cooper Union experience. Other reports are a brief review for those with general interest in engineering education, and a collection of "how to" materials -- course outlines and assessment guides -- for use by faculty members as they modify courses.

It has been prepared in collaboration with Educational Facilities Laboratories, a division of the Academy for Educational Development.

CONTEXT AND BACKGROUND

In 1976, a group of faculty members at The Cooper Union began a comprehensive examination of the school's curriculum based on a review of the broad social context for the practice of engineering. With funding from the Mellon Foundation, they undertook a twenty-month project called "SHAPE," short for Synthesis of a Holistic Approach to Professional Education.

The SHAPE project proposed* three major changes to the engineering curriculum:

- increased integration between the humanities and engineering, throughout the undergraduate curriculum;
- increased use of experiential learning, providing practice in real professional settings through professional internships;
- improved teaching and fostering of professional competences.

Each of these proposed changes is now being further developed at The Cooper Union. A project on integrating humanities and engineering has been funded by the National Endowment for the Humanities, and an internship program is being initiated. The competence development program reported on here is the follow-through of the third proposed change.

The Case for Competences

The need for education in professional competences as well as technical subject matter rests on review of the demands of real professional practice today and in the future. Today's engineering graduates must be able to educate themselves in a continually expanding body of technical knowledge and must be able to move comfortably and competently among jobs and roles that require nontechnical skills.

The types of jobs that engineers hold are more varied than they have been in the past, and surveys show that after five to ten years of professional

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*A complete report on the SHAPE program is available: "A Plan for a Holistic Approach to Professional Education - A Report to The Andrew W. Mellon Foundation," Oct. 1977, The Cooper Union.

practice very few people are working in the exact area for which they trained. The Cooper Union review group identified three quite different characteristic roles that engineering graduates should be educated to fill:

> "manager/entrepreneur" -- who assesses complex situations involving people, besides the strictly technical problem, selects and molds a team, and manages the team through problem resolution.
>
> "designer/inventor" -- who mostly innovates at the technical level in the area of systems, products or components design.
>
> "analyst/academic" -- who works principally in research, developing and applying engineering science.

Taking into account changing technological knowledge, movement among jobs, and the three broad categories of engineering roles, project faculty developed a list of competences or abilities necessary to successful professional practice. Competences identified include: fundamental principles and concepts, problem-solving, discipline, values, information, methodologies, and basic skills. The full list is shown in Chart One.

Although the list of skills is one that most would agree students should learn, and most would hope they do learn, development of these skills is not an explicit part of the engineering curriculum. They are not systematically encouraged by schools; students are not held accountable for their mastery nor teachers for their fostering.

The conclusion of the faculty group was both modest and revolutionary: that greater efforts were needed to assure, and indeed require, that students develop competence skills to a level adequate for professional practice. The faculty group further proposed that competences should not be taught as separate courses, but should be infused in the subject matter curriculum. They judged that the four-year undergraduate curriculum, packed with technological and scientific subjects, could not be expanded to include more separate courses.

The National Science Foundation was asked to support a pilot project in competence development within a small group of courses at The Cooper Union. The goal would be to make a preliminary trial and assessment of the feasibility and value of modifying standard courses to increase emphasis on professional competence, without reducing the subject matter content of the courses.

CHART ONE: COMPETENCES NEEDED FOR SUCCESSFUL PROFESSIONAL PRACTICE

* fundamental principles and concepts
* problem-solving
  - analysis and synthesis
  - innovation
  - relating problems to wider context
* methodologies
* values
* human development and relations
* information (gathering and delivering)
* discipline
  - reliability
  - thoroughness
  - productivity
* action
  - planning
  - organizing
  - self-confidence
* basic skills
  - communication
  - computation
  - experimentation

PROJECT DESIGN

The competence program at The Cooper Union was implemented over a three-year period. During that time, seven project faculty members modified eight courses in the engineering curriculum. Students were recruited from three successive entering freshman classes to participate in the program by taking the competence version of available courses. A series of evaluation surveys, and interviews with faculty and students were undertaken throughout the pilot project.

COMPETENCES

Of the nine competences identified by the Project SHAPE faculty, three were selected for inclusion in the NSF pilot program: problem-solving, communication, and value clarification. These three were selected for several reasons:

- These competences are central to successful professional practice and have been discussed among engineering educators for many years.
- These three competences were most congruent with the interests of the NSF DISE program.
- The American College Testing Program had developed a standardized test of these three competences which could be used to measure student achievement.

Briefly, the three professional competences were defined as follows:

Problem-solving: Ability to analyze problems, synthesize data, relate problems to a wider context, and develop and implement solutions.

Communication: Ability to listen to others, to receive and send information through writing, drawing and speaking, and ability to keep in mind the other person while communicating.

Value Clarification: Ability to recognize one's own values and others', to understand how they influence problem definition and solution.

A schema of three levels of proficiency was then developed and applied to each of the competences. (See Chart Two). Each level represented increasing depth and complexity of mastery. Together, the three competences and three

CHART TWO: COMPETENCES AND LEVELS OF PROFICIENCY AS USED IN THE COOPER UNION PROFESSIONAL COMPETENCE DEVELOPMENT PROJECT

Problem Solving	Communication	Value Clarification
Level 1: Demonstrate ability to formulate assumptions and identify implicit and explicit elements so as to be able to apply simple common principles and methodologies in specific situations to obtain a realistic solution.	Level 1: Demonstrate ability to receive and send information via oral or media presentation, non-verbal cues, written materials, numerical and graphical representatins in standard academic assignments. (Here, the emphasis is to be on psychomotor skill, coordination, poise, speech habit, voice training, grammar, computational accuracy, consistent use of symbols, neatness, clarity of work presentation.	Level 1: Demonstrate ability to identify one's own values and their sources as they relate to a specific situation by observation of one's own attitude, opinions, feelings, thoughts, beliefs, goals and morals.
Level 2: Analyze situations new in configurations but similar to known ones in substance; identify relationships in a given system or situation. Recognize needs and synthesize alternative proposals and problem-solving strategies. Carry out a project within a well-defined field, interpret results, critique own and other works in the area. Draw conclusions for further action.	Level 2: Demonstrate the ability to use these skills in situations involving prepared presentation (oral papers, writen reports, participation in formal debates).	Level 2: Demonstrate understanding of the philosophical, religious or cultural and social basis of values and of the development of science and technology as a reflection of values (in different traditions and civilizations).
Level 3: Analyze situations new in substance and configuration with strong interdisciplinary elements. Synthesize alternative proposals and problem-solving strategies for these cases and carry out their execution. Establish relations to a wider context. Exhibit critical spirit. Show proof of imagination and innovation.	Level 3: Demonstrate the ability to use these skills in actual involvement at the professional level. Creative and original use of skills.	Level 3: Demonstrate ability to apply in specific situations one's understanding as defined in Level 2, to analyze the implications and effects of held values.

levels of proficiency formed the conceptual basis for modification of specific courses.

FACULTY TRAINING

Nearly all participating faculty members had been actively involved in Project SHAPE, 1976-77, which led to the development of the current project. Through their involvement they had developed an intimate familiarity with the concepts of professional competence development.

Four special one-day workshops were held at The Cooper Union for all participating faculty members in the Spring of the 1979-80 academic year. Faculty members from Alverno College presented workshops on communications and value clarification. Dr. Donald Woods, of McMaster University, presented a workshop in problem-solving and Dr. Jean LeMée, project co-director, presented a workshop on developing competence courses.

In addition, three participants attended workshops of The American College Testing Program on competence achievement testing, and two week-long workshops on competence development and assessment at Alverno College.

COURSES

Eight courses, ranging from required elementary courses to advanced electives, were selected for modification as competence-based courses. The courses included science, engineering, social sciences, humanities and interdisciplinary courses. Chart Three describes the courses included in the project, and Chart Four illustrates the sequence in which courses were developed and offered to incoming student groups.

Participating faculty members were responsible for selecting the competences and proficiency levels for which they would modify one or two of their regular courses. Course modifications were made independently. Faculty teaching load was reduced by one course during the term in which they reviewed and modified their courses. Their experiences in adopting the general principles to what were traditional and highly technical courses were part of the subject of the project.

CHART THREE: COURSES MODIFIED AT THE COOPER UNION

H 18.1 Basic Humanities. Studies in classic and contemporary genres: works of poetry, fiction, drama. Music, film and theatre experiences. Intensive instruction in imaginative and expository expression, both written and oral. Instruction in the writing of research papers and use of library resources. 3 credits. (Required)

S 23.2 Introduction to Politics. This introductory course in Political Science focuses on the study of power relationships in public affairs. It is designed to provide a basic understanding of political behavior, of the institutional structures which are the setting for political activity, and of some of the political issues -- perennial as well as current ones -- that we face. Although the readings deal specifically with the American system, many of the concepts encountered have a more general application and will be considered in a broader context wherever possible. 3 credits. (Required)

Ph 12 Mechanics. Fundamental physical concepts and conservation laws; kinematics and dynamics of particles and rigid bodies; mechanical interpretation of thermal phenomena. 4 credits. (Required)

Ph 91 Introductory Physics Laboratory. Physical measurements and analysis of experimental data. The experiments and instruments relate to the principles and applications of several areas of classical and modern physics including, among others, wave motion, electricity, (particularly use of analog and digital meters and the oscilloscope), spectroscopy and radioactivity. Quantitative consideration of random and systematic uncertainties. 1 1/2 credits. (Required)

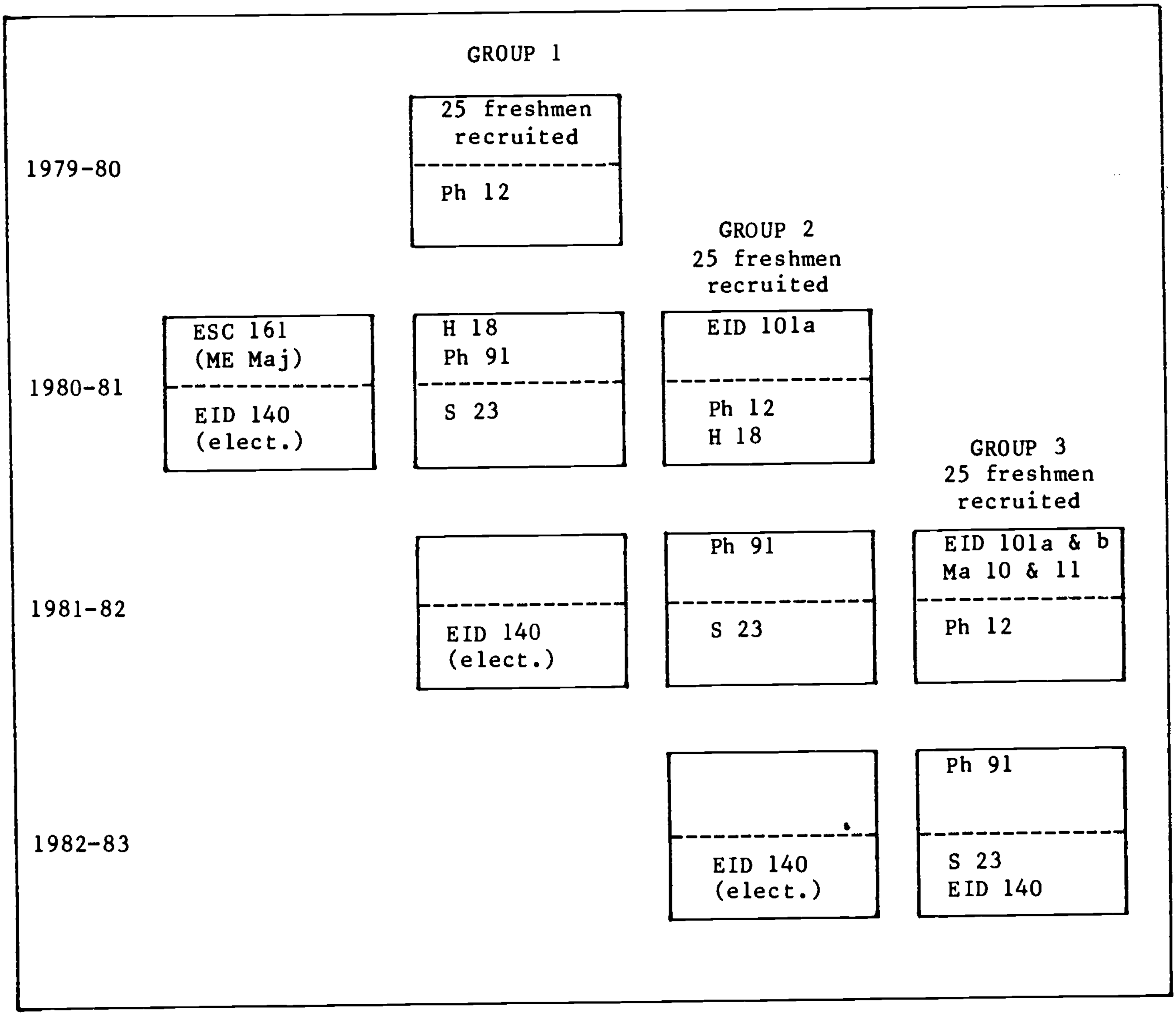
EID 140 Environmental Fundamentals. The nature of the environment--air, water, land and solar radiation interrelationships. Demographic trend, material and energy demands and the environment. Sources of environmental pollution and legal activities toward their control. Facts affecting pollutant levels in the atmosphere. 3 credits. (Elective Seminar)

Ma 10 and 11 **Analytic Geometry, Vectors and Matrices and Calculus.**
Ma 10: Plane analytic geometry -- conic sections, translation and rotation of axes. Vectors in two and three dimensions; vector algebra, inner product, cross product and applications. Analytic geometry in three dimensions -- lines, planes, spheres, quadric surfaces. Matrix algebra -- solution of systems of linear equations, determinants, inverses, characteristic values.
Ma 11: The derivative and applications -- curve sketching, maxima and minima, velocity and acceleration; trigonometric, exponential, and logarithmic functions; inverse functions. Definite and indefinite integrals; area, work, arc length. The fundamental theorem. Techniques of differentiation and integration. Total 6 credits. (Required)

EID 101 **Engineering Design and Problem Solving I--Space Concepts** and **Guided Design.** The course emphasizes three-dimensional space concepts, conceptual blockbusting, problem-solving methodologies, and graphical techniques in the context of enginering design and problem-solving. Several design projects, specifically chosen to meet the above objectives will be undertaken by students, both individually and in small groups. The format of guided design, focusing on the systems approach to problem-solving, is used for all design projects. Oral presentation and formal written report are required for each project. Professional attributes, human values and social qualities are stressed in engineering problem-solving. 3 credits. (Required)

ESC 161 **Linear Systems.** Mathematical and graphical representation of physical components and systems (mechanical, electrical, fluid, thermal, etc.); analogies; linearizations; steady-state operation, Laplace transforms; transfer functions; state-space description; transient response; analog computation. 3 credits. (Required of Mechanical Engineering Majors)

CHART FOUR: SEQUENCE OF COMPETENCE COURSES AT THE COOPER UNION



H 18.......Basic Humanities
S 23.......Introduction to Politics
Ph 91......Introductory Physics Laboratory
Ph 12......Mechanics
Ma 10......Analytic Geometry, Vectors and Matrices
Ma 11......Calculus I
EID 101....Engineering Design and Problem Solving I (ME majors)
ESC 161....Linear Systems (ME majors)
EID 140....Environmental Fundamentals (open elective)
101a = guided design
101b = graphics

PARTICIPANTS

For three years, all incoming freshmen were invited to sign up for the project. Approximately the first twenty-five to apply were admitted, forming one course section. Comparison of the records of students entering the program and nonparticipating students showed no significant statistical difference regarding SAT scores or other measures of academic achievement. Once accepted, the students enrolled in the competence-based version of courses wherever available. The intent was to develop a sequence of courses so that a student who elected to participate would have sustained exposure to courses taught in this manner.

EVALUATION

Project design included several mechanisms for on-going evaluation of the project and specific courses by faculty, students, and outside reviewers. In addition, a standardized competence achievement test was to be used at the beginning and end of the project to see whether progress could be measured and compared between participating and non-participating students.

Advisory Board. An advisory board of experts in engineering, competence, and assessment from academic institutions and industry was formed to provide guidance and feedback to project faculty. The board met four times, for one- and two-day sessions, at The Cooper Union during the course of the project. They received reports, heard student and faculty presentations, observed classes and sample videotapes, and gave advice to project directors and faculty.

Surveys and Questionnaires. An outside professional firm, Formative Evaluation Research Associates (FERA), was engaged to develop survey forms for soliciting detailed student reaction to specific courses and the program and to compile results for project faculty. Once during the project FERA conducted interviews with project faculty and nonparticipating faculty to probe their experiences and reactions to the project.

Standardized Achievement Test. The Cooper Union worked with The American College Testing Program (ACT) to administer and evaluate the effectiveness of two standardized competence achievement tests developed by ACT to measure and compare achievement among participating and nonparticipating Cooper

Union students. ACT cooperated in providing and interpreting several different scoring methods. The final comparative test between participating and nonparticipating students will be administered in 1982-83 academic year.

OBJECTIVES

The project was designed to implement, analyze, and report on modification of existing courses for systematic attention to competence development. Actual course modifications were carried out under conditions typical of curriculum development at The Cooper Union: Workshops and guided readings were available to faculty and opportunities for collaboration and discussion were provided. However, participating faculty members were individually responsible for course development.

A series of questions was posed for observation and analysis during the course of the project:

Changes

- How would courses be modified without loss of technical content to make them 'competence-based?' For example, what changes would be made to course organization, use of class meeting time, lectures, tests, and assignments?
- What specific techniques would be developed for fostering and assessing competence development?

Competences

- How appropriate and useful would the three competences and the three proficiency levels prove to be?
- How easy or difficult would it be to modify different types of courses to include emphasis on competence development? (And for each of the three competences?)

Impact and Assessment

- How easy or difficult would it be to assess students' attainment of competences? (And at each of the three proficiency levels?)
- Could the cumulative impact of several competence-based courses on student proficiency in each of the three competences be measured and compared with the performance of students taking only regular courses?
- Could comparisons be made in subject matter mastery?

Relationship to Rest of Academic Program

- Can one successfully add competence emphasis to an existing course while maintaining subject matter content?

- Operating within the basic structure of a traditional engineering curriculum, what proportion of a student's courses should emphasize competence, and what should be the relationship to the rest of the academic program?

- What lessons, if any, could be drawn about the suitability of this approach to different types of students and faculty? What are the implications for wider inclusion in the educational program?

Faculty Response

- How comfortable would faculty members feel modifying courses, and fostering and assessing competence among their students? (And for each of the three competences?)

- How would faculty evaluate the amount and type of training and support they had in making and implementing course modifications?

- How would participating faculty compare the experience, demands and rewards of teaching courses in their regular style and in the competence emphasis?

- How would non-participating faculty view the project?

Student Response

- How would the student participants react to the course modifications and to the project?

Recommendations

- Based on the experience at The Cooper Union, what recommendations could be made to other schools about emphasizing development of professional competences as well as subject matter mastery?

PROJECT CHRONOLOGY

The chart on the following pages identifies the chronology of key events in the Cooper Union competence project.

CHART FIVE: PROJECT CHRONOLOGY

1979-1980 ACADEMIC YEAR

SEPTEMBER - JANUARY (FALL TERM)

National Science Foundation Grant awarded
Weekly meetings of participating faculty
Consultation with ACT* re competence tests
Consultation with FERA** re evaluation plan development
25 students recruited from freshman class
Development of Basic Humanities course
Development of Mechanics course

FEBRUARY - MAY (SPRING TERM)

Mechanics course given, first time, to freshmen

February
Early course evaluation questionnaire administered

February - March
Four one-day workshops given for participating faculty:
Problem-Solving: Donald R. Woods, McMaster University
Communications: Staff of Alverno College
Value Clarification: Staff of Alverno College
Competence Course Development: Jean LeMée, The Cooper Union

March
ACT short test administered to 40 freshmen: 25 in NSF program, 15 not in program

May
Advisory Board Meeting
Post course evaluation questionnaire administered

SUMMER

Three faculty members attended one-week Alverno College assessment workshop
Letter sent to incoming freshmen, and 25 accepted into program

Development of Introductory Physics Laboratory
Development of Linear Systems course
Development of Environmental Fundamentals course

* ACT = American College Testing Program
**FERA = Formative Evaluation Research Associates

1980-1981 ACADEMIC YEAR

SEPTEMBER - JANUARY (FALL TERM)

Basic Humanities course given, first time, to sophomores
Introductory Physics Laboratory given, first time, to sophomores
Linear Systems course given, first time, to juniors

Development of Introduction to Politics course

September
Early course evaluation questionnaire administered
ACT long test administered to 41 freshman: 24 in NSF program, 17 not in program

November
Advisory Board Meeting
FERA letter to participating faculty re student early course evaluation questionnaire
FERA interviews with six participating faculty

December
FERA summary of faculty interviews distributed to participating faculty

January
Post course evaluation questionnaire administered

FEBRUARY - MAY (SPRING TERM)

Basic Humanities course given, to freshmen
Mechanics course given, to freshmen
Introduction to Politics course given, first time, to sophomores
Environmental Fundamentals course given, first time, to juniors/seniors

Post course evaluation questionnaire administered

SUMMER

Development of Analytic Geometry and Calculus I course
Development of Engineering Design and Problem Solving-I course

June
Advisory Board Meeting

1981-1982 ACADEMIC YEAR

SEPTEMBER - JANUARY (FALL TERM)

Analytic Geometry and Calculus I course given, first time, to freshmen
Engineering Design and Problem Solving-I course given, first time, to freshmen
Introductory Physics Laboratory given, to sophomores
Linear Systems course given, to juniors

September
Early course evaluation questionnaire administered
FERA distributed a summary of the early course and post course student evaluations of Spring 1980 courses to each participating faculty member

October
FERA summary critique on competence assessment, including student reactions to Fall 1980 and Spring 1981 course assessments

November
FERA interviewed 24 faculty members not in the project

December
Advisory Board Meeting

January
Post course evaluation questionnaire administered

FEBRUARY - MAY (SPRING TERM)

Mechanics course given, to freshmen
Introduction to Politics course given, to sophomores
Environmental Fundamentals course given, to juniors

February
FERA reported interview findings from November 1981 to faculty

March
FERA submitted summary of Fall 1980 semester post course evaluation assessment

May
ACT competence test administered to some students who had been in the project two years, and to some students in the regular program of study

1982-1983 ACADEMIC YEAR

SEPTEMBER-JANUARY (FALL TERM)

Introductory Physics Laboratory given, to freshmen
Competence version of Engineering Design and Problem-Solving replaced regular version, for all freshmen

September

ACT competence test administered to remainder of students who had been in the project two years, and to comparable number of students in the regular program of study
FERA final project evaluation report submitted
Project reports finished

FEBRUARY-MAY (SPRING TERM)

Introduction to Politics to be given, to sophomores
Environmental Fundamentals to be given

PROJECT ANALYSIS

The questions posed in the project design section provide the structure for the following detailed project description and analysis of lessons learned.

Changes

- **How would courses be modified without loss of technical content to make them 'competence-based?' For example, what changes would be made to course organization, use of class meeting time, lectures, tests, and assignments?**

The courses modified as competence-based courses had been taught before by the same faculty members. They included a physics lab course; a graphics and design course; several science, engineering, and math courses; and courses in social sciences and humanities.

The wide range of teaching styles and course designs practiced at the school makes generalization risky. Nonetheless, the courses that were modified for this project had been quite traditional in their design when taught "regularly." More often than not, the courses had had structured lectures by the professor, and a recitation period in which students asked questions or professors went over homework assignments. Courses had tended to use one or two text books. Student assignments had been tied in to text book readings and problem sets, and had been assigned nightly or weekly and completed independently.

Many of the course modifications reported by participating faculty were similar, and can be grouped under a few headings. Taken collectively, they describe the major differences between courses taught under the competence program and the same courses taught in the "regular" manner. (See Appendix A for a course-by-course description of key features of course modifications.)

Increased Intensity and Focus

Faculty felt that the most important change was an increased focus and intensity to the course. They reported greater awareness, on their own part and that of students, of the nature of professional practice and of the underlying goal of professional education. They related assignments, class discussions and comments much more to examples drawn from professional practices that students would likely meet.

Bringing awareness of the importance of competence development, as well as subject matter mastery, to the forefront was an important change. Public classroom discussion of presentation techniques was new for these students.

Discussion of competences, of explicit standards of performance, above and beyond numerical and conceptual accuracy, was also a new feature.

Increased Structure of Course, Shared with Students via Study Guides and Assessment Manuals

Many faculty members developed detailed study guides for the first time. These documents laid out the course work, week by week, for the entire term. They were part syllabus, lesson plan, lecture notes, and assignment plan. The study guides often were divided into course modules, and described objectives and concepts to be mastered in each. Some included supplementary materials, and tips and advice on using the course text.

Sharing syllabus type information with students was also new. Some faculty gave students the whole study guide at the beginning of the term; others handed out sections during the term. Those who handed out the entire guide early on felt that it allowed students the opportunity to better pace themselves during the term, allowing them to get ahead or catch up depending on their other commitments. They felt this helped develop responsibility among students. Those who handed out the study guide piecemeal felt that it allowed better control of student's work and helped students to be better prepared.

Assessment manuals, developed by faculty as companions to study guides, provided some of the philosophical underpinnings of competence development. They also gave expectations for competence performance during the course.

(Appendix B contains sample excerpts of Assessment Manuals and Study Guides. The third report in this series has detailed information on specific course materials developed at The Cooper Union.)

More Student Work as Teams

In the "regular" version of courses, almost all student work had been done individually.

The abilities to work effectively as a team member, to assume responsibility for team performance, and to be a leader when called on, were identified as important to professional engineering practice.

Therefore, many of the courses were modified to provide opportunities for and/or to require students to work together in pairs, in groups of four to six, and occasionally as a full class. Group work included discussion and problem-solving, class groups in design and math, joint lab reports by lab partners in physics, out-of-class preparation of reports and presentations in several courses, in-class oral presentations and seminars, and videotaped presentations.

More Presentations by Students to Students

In the "regular" courses, most interactions had been between individual students and the professor. Homework assignments and tests had been most often written, and turned in to the professor, who had returned them with comments and grades. The professor had been almost always at the head of the classroom, lecturing, fielding questions, or leading a discussion.

In competence-based courses, students very often performed before each other -- individually or as a team -- and evaluated each other. Students were expected to go to the blackboard and teach one of the homework problems. They gave seminars and lectures to the class, or led and participated in round table discussions. The ability to take an active role in presenting ideas and conclusions in person had not been fostered or practiced much before in these courses, but faculty agreed they were crucial to professional competence.

In an interdisciplinary environmental science course, all 45 hours of class meetings had been lectures in the "normal" version. In the first year of competence-based study, ten of the class hours were given over to student-prepared presentations.

Use of Video Technology

Video technology was introduced as a means of enhancing and assessing personal presentation skills. None of the courses had used videotape before, but all of the competence-based courses made some use of video. Each course required at least one videotaped presentation.

An A/V lab at The Cooper Union, staffed with technicians, was made available to students in the program and a consultant was hired to help students learn how to give oral presentations. Technicians were also available to tape presentations made in the classrooms.

Videotapes were used in three ways:

- To record a "live" presentation in front of the class. (Students were assessed on the basis of the live performance, but could later view that performance on tape.)
- To rehearse and prepare for live presentations. (Use for this purpose was less than anticipated.)

- To create a finished tape for an assignment. (In making a tape, students could practice or repeat until they were satisfied at the lab. Faculty members reviewed and graded tapes as they would any other assignment. This allowed for evaluation of individual performances without taking classroom time.)

Greater Variety in Class Assignments and More Use of Real Life Simulations

In many of the "regular" courses faculty reported that assignments had typically been limited to text book problem sets, listing definitions of terms and concepts, and standardized exercises. Often a single book was used as the text for a course.

Although these assignments were not entirely abandoned, other assignments requiring greater depth and breadth of reading, thinking, and presentation were added or substituted. Science courses included readings beyond a text. In a politics course, students had to attend and analyze a New York City community planning board meeting in terms of the power theories they had studied. Students had to give formal in-depth technical presentations -- individually or as a team -- on topics that were the subject of a physics lab or an applied calculus problem. The presentations required preparation of graphs, charts and other materials.

Many assignments were structured to simulate real life situations. For example, in preparing lab reports, students had to explain the problem and its importance, and describe alternate ways of testing hypotheses and reasons for selecting the one used. They had to design and use data collection and analysis forms, and write a coherent analysis and conclusion. The complete lab reports more closely resembled the type of experimental documentation required in professional practice. In another example, a test in mechanics required not just a numerical answer, as before, but also statements of assumptions and constraints, and various possible approaches to solving a problem.

Whole classes worked together on a team report that approached a real life problem. For example, a class on environmental problems developed a policy report assessing whether or not to recommend that New York City taxis be required to convert to diesel fuel. Another class used simulated development of a small self-sufficient community as the means for studying a number of engineering design strategies and public policies.

Individual student assignments also came closer to real life and grew in complexity: fill in for the pollution agency chief on short notice, and give a five-minute presentation on the agency; analyze the President's inaugural address as an editorial; give a formal engineering presentation (written and oral) as you would at a professional conference.

Longer Assignment Periods

Many of the competence courses introduced multi-week assignments for the first time. All assignments to student teams took several weeks to plan, research, and prepare, whether the final product was a written report, oral presentation before class, or a videotape. Assignment periods were from two to seven weeks, and at least one course was structured around preparation of a single large report representing an entire semester's work. Long term individual projects were also introduced in a few classes. The thrust to develop real life assignments resulted in longer assignment periods.

More Work

A cumulative effect of all the other changes and modifications was that the competence-based courses required much more work of both students and faculty than they had in their "normal" versions.

A ground rule of the NSF project was that the courses be modifications of existing courses and cover the same academic materials. Many of the courses had been given in a format of lecture periods and recitation sessions. This structure was maintained, with little, if any, change in the formal lectures.

Most changes, therefore, were made in the recitation sessions and in the out-of-class assignments. At least one course added four, 3-hour sessions to the class schedule to accommodate student-led seminars on laboratory experiment topics. Writing essays, making videotapes, and preparing thorough lab reports all took more time than the assignments they replaced. They also required more effort of faculty than had earlier assignments, particularly since the faculty were committed to reviewing assignments in terms of presentation techniques, as well as technical content.

- **What specific techniques would be developed for fostering and assessing competence development?**

Faculty members made no clear distinctions between fostering competence and assessing competence. Most subscribed to the opinion that the best way to learn was to practice. Therefore, many opportunities were provided for practicing competences, accompanied by frequent and detailed feedback on performance. Feedback was a combination of criticism and praise, and suggestions for change and improvement. All homework assignments, lab reports, essays, presentations, classroom discussions, and tests were considered opportunities for assessment and practice. Several teachers also scheduled regular private meetings with students.

Faculty members did not design special exercises, tests or assignments to foster or assess a specific competence in isolation. Instead, they revised class work and assignments to provide practice in communication and problem-solving as well as subject matter. Raising the general level of expectation and awareness, which faculty said was a key change, was accomplished through lectures and discussions, assessment manuals, and instructions for out-of-class assignments. Tests and assignments reflected the new orientation, as described above.

Take an example from the calculus course. In addition to doing problem sets for homework, students had to anticipate being called on to solve a problem at the board and successfully answer questions from other students. What perhaps is unusual is that the student at the board was not talking to the teacher, but to other students, and that the student was expected to present a clear, logical solution -- legibly and neatly written and well spoken. The student could expect feedback from the professor and other students on the manner and organization of the presentation, as well as on the accuracy of the solution.

Students in the same calculus class worked in groups of four to six on scientific phenomena that could be explained with calculus -- the physiology of breathing, for example. They had to make a 30-minute team presentation, complete with illustrative materials. Organizing themselves, dividing the work, finding and calculating the information, coordinating parts of the presentation, preparing materials, and carrying out the production obviously provided practice in problem-solving and communication in many ways as well as developing other skills likely to be needed as a professional engineer. The team could expect to get critiques from other students and the professor. They might hold a de-briefing afterward and critique themselves -- or if it was videotaped, watch their presentation on tape.

Written materials were judged for content, organization, style, grammar, and legibility. Graphs and models were judged for comparable qualities. Every lab report had a cover sheet checklist which students and professors could use to evaluate the presentation and organization of the report.

The overall message was, "Everything counts, if you are to behave and perform competently and professionally."

Competences

- **How appropriate and useful would the three competences and the three proficiency levels prove to be?**

Originally, the project had established three competences -- problem-solving, communication, and value clarification -- and three levels of mastery for each as the guiding matrix. This matrix was distinct from any subject matter. In practice, the neatness of this theoretical construct blurred.

Careful consideration of the modifications actually made to the courses and of the larger list of professional competences derived from the SHAPE project (Chart One) shows that course changes served to strengthen almost all the competences from the longer list. The three singled out for attention really formed a framework around which faculty members thought about what professional skills students need to develop and how courses could be modified to consciously help develop those skills.

A more realistic description of what took place and a more useful reference for future work might be development of a series of skills or competences needed for professional activity.

Given that three competences -- problem-solving, communication, and value clarification -- were the reference points, though, faculty and students shared difficulties in applying all three equally to all courses.

Problem-Solving: Problem-solving is almost universally considered to be second nature to engineering; many people feel it is taught adequately already. The changes introduced were subtle, but important. Faculty placed more stress on students' ability to define a problem, to understand alternate approaches for solving any problem and reasons for selecting among approaches, to clearly explain the solution process as well as the solution, and to place the solution in a wider context.

Communication: Communication received the most attention, and was responsible for the most visible changes and new requirements in the program. Emphasis on communication was significantly different from normal courses: most had not required any public speaking or presentation, or any essays or written prose assignments before being modified for this program.

Communication was recognized by faculty and by students as needing attention and practice. Faculty _not_ in the program noted that students in the program performed better than most; students reported that their communication skills improved markedly.

Value Clarification: Value clarification was the most elusive of the competences and the most difficult to apply. It forces faculty and students to examine what motivates them in developing the solution of a problem, for instance, or what governs the existence of commonly accepted institutions and practices. It can therefore be unsettling at times. It requires a willingness on the part of all who participate to look at causes and motivations objectively and freshly. Though most faculty and students grappled with values clarification, few felt very comfortable with it.

Competence Levels

The concept of three levels for each competence proved useful mostly for background. Even though faculty set out to define expectations in terms of levels, there was general consensus that the levels were of limited worth, at best, in the classes themselves. Almost all the courses set out to accomplish levels 1 and 2 for problem-solving and communication, and a couple attempted early levels of value clarification. Most faculty members would recommend not introducing the levels into course materials, but felt that the simple-to-complex axis characterizing the levels of mastery was a useful concept in thinking about competence development.

- **How easy or difficult would it be to modify different types of courses to include emphasis on competence development? (And for _each_ of the three competences?)**

The competence-based courses covered a variety of subjects and types of courses: graphics and guided design, introductory politics, calculus and analytic geometry, introductory physics, physics laboratory, engineering systems design, and an advanced seminar on environmental issues.

Faculty reported that the emphasis on communication was useful and applicable to all kinds of courses. Since "problems" in problem-solving were considered mostly as engineering problems, there was some difficulty in applying this to nontechnical courses. The value clarification competence was easier to apply in design courses, though discussion of values also came naturally in the politics and humanities courses.

Impact and Assessment

- **How easy or difficult would it be to assess students' attainment of competences? (And of each of the three proficiency levels?)**

Faculty were confident in their ability to assess relative progress in competences of communication and problem-solving, less so with value clarification. The achievements of their students, however, were broader than just the competences identified -- faculty perceived growth in all aspects of professional skills.

The three proficiency levels, although used to establish general goals, were not used as markers to assess student achievement, nor did faculty feel it would be useful to attempt to do so.

- **Could the cumulative impact of several competence-based courses on student proficiency in each of the three competences be measured and compared with the performance of students taking only regular courses?**

Attempts to gain any short-term, objective measure of the cumulative impact of the competence courses were disappointing, and it is too early to have any meaningful feedback from former students who have become practicing professionals.

One reason for selecting the three competences was that the American College Testing Program had developed a standardized competence test which project designers hoped to use. A number of problems developed, however. Because of the high quality of Cooper Union students, incoming freshmen scored too high on the objective test, when calibrated for freshmen from eight other schools. Their scores would not have left sufficient room to measure improvement. The tests were then rescored, using a norm for seniors from fifteen colleges. The rescoring lowered the scores to provide room for improvement, although still high relative to the norm. ACT cautioned that there were comparability difficulties, however, in using this scale for The Cooper Union students. There was no statistically significant difference in performance between students entering The Cooper Union who participated in the program and those who took the regular courses. A follow-up test comparing those who have had sustained exposure to the competence program and a control group of those who have taken only regular courses, has not been completed.

A more subjective assessment was attempted through interviews with Cooper Union faculty by consultants. These faculty, who taught classes with students in the NSF program and not, were asked whether they could see any impact of the program on student performance. In the areas of problem-solving and value clarification, they saw no difference; in the area of communication about half felt they saw a difference.

Students, in course surveys, reported marked improvements in their communication skills due to their NSF courses, some in their value clarification and little to none in problem-solving.

- **Could comparisons be made in subject matter mastery?**

Students at The Cooper Union do not take standardized achievement tests, so there is no mechanism for direct comparison of subject matter mastery between students in the competence-based program and not.

Subjectively, participating faculty members were sure that students in their competence courses learned as much, if not more, than students who took those same courses in their "regular" version.

Relationship to Rest of Academic Program

- **Can one successfully add competence emphasis ' an existing course while maintaining subject matter content?**

The premise for this project was tha; professional schools should be educating y^ung people with both techn'.cal knowledge and the general competence skills nece. -v to succeed .. professionals, and, furthermore, that competence development had already been sacrificed to subject matter.

The challenge in this project was to infuse competence awareness and learning into existing courses without changing or diminishing the subject matter content. All faculty felt they were able to do this, for communication and problem-solving.

However, in order to accomplish this, the courses required considerably more work of both students and faculty than they had before. Extra work was required outside the classroom for assignments, as described earlier. One course added additional meeting periods for discussion of laboratory experiments. A small advanced elective course exchanged faculty lectures for student presentations, and required students to pick up some subject content through outside reading alone.

. Operating within the basic structure of a traditional engineering curriculum, what proportion of a student's courses should emphasize competence, and what should be the relationship to the rest of the academic program?

Because of the extra work these courses required of faculty and students, clearly not all courses could be transformed to the extent that the trial classes were. Neither students nor faculty could cope. What remains to be tested is how much of the curriculum should be transformed, and what smaller modifications could be made to other courses to reinforce the competence aspects of professional education.

During the Cooper Union project, students took about two out of five courses per term as competence courses. Given the extra work required, this seemed about the limit that they could sustain. Participating faculty members taught one or two competence-based courses at a time. They recommended that only one such course be taught by any person, because of the added work. This work was not only grading papers and more complex assignments, but viewing videotapes, and many more personal conferences with students.

Many faculty felt that competence development should be started and emphasized in the first years of the students' program. Recommendations of the participating faculty were that competence-oriented courses be introduced in the freshman year, with perhaps two out of five or six courses per term for the first two years as "competence courses." For the last two years they recommended that perhaps one course every other term stress competence development at a more advanced level.

Several faculty members were concerned that standards of performance and presentation developed in the competence courses be reinforced by high expectations in all courses. For example, if organization, grammar, and legibility were stressed in written assignments in a competence course, then subsequent courses should also expect these qualities. They felt that without continued reinforcement, the impact of the competence courses would be diluted. The message that students would get would be that competence courses were idiosyncratic, rather than that they developed necessary professional standards of performance.

- **What lessons, if any, could be drawn about the suitability of this approach to different types of students and faculty? What are the implications for wider inclusion in the educational program?**

Students

The Cooper Union experience suggests that a competence orientation is well-suited to some students and ill-suited to others. The numbers are too small to be able to claim any rigorous generalizations, but the observation suggests the need for some flexibility in student assignment policy.

Student participants at The Cooper Union applied to the program the summer before their freshman year, based on a description mailed to them in the spring. They were accepted on the relatively random basis of order of application, until a group of twenty-five was achieved. Once accepted, they were expected to take competence versions of courses wherever possible.

As a rough guide of whether students who enrolled in the program were markedly different from other students at The Cooper Union, enrollees and other students were administered the Briggs-Meyers personality typing test and one of the competence tests of the American College Testing Program. No significant pattern of difference appeared. The project directors feel that the student participants were roughly typical of the students who attend the school.

Some students in the program thrived -- they enjoyed it and did well; others floundered -- they disliked it and did poorly. Many students reported that it took awhile to "get the hang of it." Faculty members found it hard to categorize those who did well or poorly, but said that perhaps those who benefited the most were more mature to start with.

So long as a competence-based program is voluntary, there should probably be some flexibility to transfer, at least up to a certain point. Competence-oriented classes could be open to all interested freshmen, for example, and students could transfer to or from regular versions of the same courses during that year. At the end of the first year they would be required to make a firm commitment.

Faculty

Another lesson learned is that course modification with emphasis on competence development must be voluntary for faculty members -- it cannot be successfully mandated. Of the seven professors who participated, out of a faculty of thirty-five in the engineering school, one or two had strong reservations about how much they would continue after the trial period. Among the competences, value clarification being the most difficult to develop and assess, remained the most neglected. The three-level categories were virtually abandoned, even within the trial period. Nonetheless, most faculty members were basically enthusiastic about the experience. Faculty members who were not participants expressed a wide range of feelings, from cautious enthusiasm to scorn, about the project.

However, participating faculty felt it w d be important that all courses in a school increase the level of expectation and requirements for students. In order to accomplish this, a fair proportion of the faculty should become excited about the goals and finding ways to incorporate skill practice into their courses.

Faculty members who are most involved, therefore, would have to be responsible for keeping the rest of the faculty informed and interested. They should share what they are doing, and materials they are developing. They should invite other faculty members to observe classes and review assignments. If the school is one in which independence is highly valued -- as it is at The Cooper Union -- proponents of competence development will have to become politically sophisticated in building bridges.

Faculty Response

- **How comfortable would faculty members feel modifying courses, and fostering and assessing competence among their students? (And for each of the three competences?)**

Faculty members reported undergoing extensive and profound reassessment of their teaching. This included examining the specific subject matter of each course and how it relates to the whole curriculum and to the development of young professionals; examining the professional skills needed by a practicing engineer and exploring how they could be strengthened in a given course; considering how to design class activities, projects, and assignments to provide practice with professional skills; and considering how they as individuals could best contribute.

Most faculty members reported that the first time they gave the modified version of their course, they were preoccupied by the new competence emphasis. During the semester, and during the second offering of courses, they reported becoming more comfortable and placing more attention again on the subject matter. They adapted the competence definitions originally put forth to match their own perceptions of skills needed by practicing professionals.

Communication. Faculty members felt comfortable dealing with written communication techniques, particularly on basic items like grammar and organization. A consultant who was hired to help students and faculty with written communication was not needed. However, faculty were not as comfortable with spoken communication techniques. While they felt qualified to offer critiques, only a few felt they knew how to actively foster or teach students how to improve. A consultant for spoken communication was used in all the classes at least once. The consultant usually met with each class once before they made a videotape (a single student would see the consultant in several different classes), and would occasionally watch a presentation. The consultant was also available to the students, and met with those most in need outside the class.

Problem-solving and Value Clarification. All faculty members reported feeling comfortable with the problem-solving competence. Although they felt they sharpened their focus on it, they basically felt they already were teaching this skill, though as previously mentioned, variety of approach and emphasis on the wider context and the formulation of assumption received additional attention. Most faculty reported feeling uncomfortable with the values clarification competence and subsequently de-emphasized it.

- **How would faculty evaluate the amount and type of training and support they had in making and implementing course modifications?**

At the beginning of the project, a series of workshops was held for participating faculty members on competence development and assessment, curriculum modification, and experiences in other schools and universities. Each faculty member received written materials to supplement and reinforce the one-day workshops.

Thereafter, and by choice, faculty members worked independently reviewing and modifying their courses. Regular meetings were scheduled to review problems and compare notes, but they were poorly attended. Most changes were developed independently, with little coordination.

The NSF grant permitted faculty a reduced teaching load during the semester they had to modify their courses. This was seen as a critical ingredient. The Cooper Union's audio-visual center was also made available for student and faculty use, and technicians were available. Without this assistance, the use of video technology would not have been possible.

The speech consultant hired for the project was viewed as a valuable asset by about half the participating faculty, while the writing consultant orginally hired was considered unnecessary.

An outside educational consulting firm, Formative Evaluation Research Associates, was hired to help evaluate course development and the program as a whole. The consulting firm interviewed participating and nonparticipating faculty and developed and tabulated student surveys at the beginning and end of each term. An advisory panel of outside educators was convened twice a year to review the program.

The individual orientation of the Cooper Union faculty in the project minimized the value of outside consultants. The outside consultants, for their part, had a hard time dealing with the fragmented program. They pushed for a more coherent whole that they could grasp.

The issue of perceptions of institutional support may be worth touching on. Participating faculty resisted being dealt with as a unit, dealing with each other as a team, and keeping the rest of the school aware of the project. Over half the nonparticipating faculty were curious, but ignorant of the project and resented the poor communication from the participants. Faculty members of the project, while guarding their isolation, at the same time resented what they perceived as a lack of enthusiasm on the part of the administration.

- **How would participating faculty compare the experience, demands and rewards of teaching courses in their regular style and in the competence emphasis?**

One of the more outstanding results of the program has been that about half of the participating faculty members reported a new sense of freedom and responsibility towards the broad development of their students, beyond simply relaying technical information and skills. These professors also reported a joy and warmth in this new role. One professor may have captured it best by saying he experienced a new intensity in teaching and an almost parental concern for his students' development.

- **How would nonparticipating faculty view the project?**

Nonparticipating faculty members were not well-informed about the details of the project, which actively involved seven out of thirty-five faculty. In the third year of the project, roughly half reported little or no understanding of the project and knew no student participants.

Despite the lack of knowledge, most faculty felt the project's goals were positive and about half sensed relevance to their own work. About one third expressed interest in possibly becoming involved.

Nonetheless, overall opinion and perceptions of overall opinion tended to be negative, in part because faculty wanted to be better informed.

Of the nonparticipating faculty members who did know students in the project, many reported that the students had better communication skills and that students were enthusiastic about the communication emphasis. These same faculty members reported no noticeable impact in the areas of problem-solving or value clarification.

Student Response

- **How would the student participants react to the course modifications and to the project?**

At the beginning and end of several terms, participating students completed questionnaires about expectations and evaluations of the competence courses. (Appendix C contains the survey form used.)

It is clear that students found the competence courses very different from their other courses, not only at The Cooper Union but elsewhere. In a question asking for comparisons between types of courses, the competence courses received high ratings for communication skills and interpersonal and organizational abilities while the other courses had low ratings. Both types of courses received positive ratings for thinking and problem-solving. Ratings for competence courses in value clarification were mixed, while they were low for regular courses. Both types of courses received relatively low ratings in the other two categories surveyed -- creative abilities and personal growth.

Comments indicate that students responded strongly to the courses. Some were extremely positive and seemed to enjoy the breadth of issues -- "the human point of view" -- addressed beyond the technical subject matter. Other students, however, were discomfitted by the broader questions and would have preferred a more strictly technical approach, despite the fact that they volunteered for the project.

The FERA consultants' remarks to one professor could perhaps be expanded to the entire project: "The strengths and weaknesses of the course underscore this point about extremes. The same items appear on each list. For some, the professor, the videotapes, the communication, and the problem-solving were the course's highlights. For others, these very same points were the negative aspects of the course."

Recommendations

- **Based on the experience at The Cooper Union, what recommendations could be made to other schools about emphasizing development of professional competences as well as subject matter mastery?**

1. Be modest and conservative in goals and purposes.

   There is an inherent tension in suggesting a new program to "develop professional competence" in a professional school, since that implies that the school is not doing that now. (Especially since the inverse of competent is incompetent!) Rather, propose a program or an effort to improve, expand, otherwise build upon the base of current efforts and accomplishments.

2. Stress the underlying principles, and go easy on jargon and specific techniques.

   For example, use of videotapes is only one method of improving oral presentation skills. At The Cooper Union some phrases, such as "competence mode," caused misunderstandings which might have been avoided.

3. Develop the specifics on your own campus, being sensitive to the characteristics of your institution. Do not import somebody else's program.

   Although outside review suggested that more coordination among participating professors might have been desirable, one of the dominant characteristics of The Cooper Union is faculty individuality and independence. Unless this independence were respected, there probably could not have been a program there. The most important part of The Cooper Union project was the individual professor's review and modification of courses, based on understanding of general principles. All of the professors were reluctant to be seen as trying to "export" particular techniques or curriculum.

4. Keep the program optional and allow students to transfer out.

   Faculty members support the need to have a sequence of courses emphasizing professional competences, noting that it took many students one or two courses to "get the hang of it." At the same time, they note that the courses did take considerably more work and required motivation and maturity from the students. Not all the students who had signed up for the program found it useful, and some felt out of their element. Faculty felt these students should have the option to transfer out of the course and the program without any penalty. A few faculty wanted the prerogative of weeding out students who did not seem appropriately motivated early in the course.

5. Give faculty time off to modify courses.

   The Cooper Union faculty members took one semester to modify each course and had their teaching load reduced by one course during that time. They would strongly recommend a similar arrangement to others. At least one recommended that the teaching load reduction be carried through the first semester of implementation.

6. Provide support.

   - Administrative support that the undertaking is valued, and reaffirmation that developing professional competence is a mission of the school.

   - Opportunities to bring experienced outsiders in to consult and hold workshops, and opportunities for faculty members to visit other schools.

   - Facilities and people needed to help students practice skills. At The Cooper Union this included use of a video center and studios, availability of AV technicians to tape classroom proceedings, and a part-time public speaking consultant. A writing consultant turned out not to be needed, but faculty members lobbied for a skills development center for the whole school.

   - Some faculty members suggested that teaching assistants would be helpful.

7. Seek ways to reinforce competence skills throughout the curriculum.

   Skills developed in the competence-oriented courses need to be practiced occasionally throughout the students' school career. With the cooperation of the entire school faculty, existing courses could be modified slightly to provide significant cumulative experience. For example, two or three courses might require written essays or assignments, a few others require oral presentations, and quite a few could be modified to provide opportunities for team work among students.

IN SUM

The professional competence development project at The Cooper Union is having a pervasive impact on the school. The faculty has developed heightened awareness of the importance of broad professional education. Many courses, including the most traditional, are being reorganized with a project orientation and with new emphasis on comprehensive problem-solving skills. Faculty members who did not participate in the project are introducing more oral and written communications practice in their classes, and the school's curriculum committee is investigating methods for systematically developing communication competence in all courses.

APPENDIX A

KEY FEATURES OF COURSE MODIFICATIONS CARRIED OUT IN THE COOPER UNION PROFESSIONAL COMPETENCE DEVELOPMENT PROJECT

SPECIFIC COURSE DESCRIPTIONS AND KEY MODIFICATIONS

Ma 10 : ANALYTIC GEOMETRY, VECTORS, AND MATRICES
Required course, lower level.

Key features when taught as regular course:

* Single main text.
* Lectures and review of homework problems.

Key features when taught as competence course:

* Same text, plus supplementary texts.
* Same types of problems
* Introduced a day-by-day study guide for the entire semester. It listed the topic and expectations, homework problem sets and additional projects.
* Study guide permitted self-pacing by students of materials.
* Students worked on problems in small groups in class, and gave blackboard presentations of solutions.

Ma 11 : CALCULUS I Required course, lower level.
(Taught concurrently with Ma 10, by same professor.)
Key features when taught as regular course:

* Single main text.
* Lectures and review of homework problems.

Key features when taught as competence course:

* Same text, and same general structure.
* Group assignment towards end of semester: A group of about 5 students assigned to research a topic, using a "UMAP" module, which could be described using calculus. The group then prepared a videotape, to be as close as possible to a professional presentation, on the topic. Assignment took several weeks, and was done mostly out of class, in addition to regular homework problem sets.

Ph 12 : MECHANICS Required course, lower level.

Key features when taught as regular course:

* Two 1 1/2-hour lectures, and two 1-hour recitation periods a week
* Two "mid-term" exams and one final exam

Key features when taught as competence course:

* Same structure of lectures, recitations, and examinations.
* Use of recitation periods quite different. Five or six students would be selected to go to the board and "teach" the solution to one of the homework problems to the rest of the class, with no advance notice. Students were judged, and critiqued in class, on the quality of the presentation and the thoroughness of their understanding.
* Examinations and homework assignments had to be thorough answers, i.e., words and equations had to thoroughly explain the reasons and process of reaching the solution. A single correct numerical answer was insufficient.
* Mid-semester, students had to make a studio videotape presentation of teaching a problem, and turn it in as an assignment. Thereafter, recitations included live and taped performances.

Ph 91 : INTRODUCTORY PHYSICS LABORATORY Required course, lower level.

Key features when taught as regular course:

* Standardized, specified set of ten laboratory experiments.
* Students do experiments, fill in lab exercise sheets, and turn in; limited class discussion.

Key features when taught as competence course:

* Essentially same set of laboratory experiments.
* Nature of the lab report quite different. Students required to prepare complete reports. This included designing data sheets to collect and report on all data, drawing pictures of equipment set ups, establishing theory and justification for the experiment, and so on. Students were graded for content, and for presentation.
* Four additional, 3-hour, sessions added to the class. These sessions used for lab teams (composed of six students) to give a one and a half hour seminar to the class, elaborating on one of the laboratory experiments in depth.
* Presentation and discussion sessions were videotaped.
* Students worked in pairs, and each pair turned in a single lab report.

S 23 : **INTRODUCTION TO POLITICS** Required course, lower level.

Key features when taught as regular course:

* Class enrollment about 30
* Essentially a descriptive course
* Class time a combination of discussion, review of assigned reading materials, and questions.
* Homework assignments for each class meeting based on readings; tended to be to define a list of terms and questions.
* Take home essay examinations

Key features when taught as competence course:

* Class enrollment about 20 -- able to have less lecturing and more discussion
* Reoriented the entire course around the theme of "Politics as a form of communication" -- more analytical than descriptive
* Replaced a course section on current issues with a section on community politics and power
* Traditional assigned readings retained, but additional, and quite different homework assignments added. These included, for example:
  . attending a community board meeting, summarizing issues, and relating the meeting to assigned readings on community power
  . writing a letter to a friend about government's right to intervene in private sector affairs
  . individual videotaped presentation on corporate accountability, and recommendations for congressional and administrative reform measures
  . small group videotaped round table discussion of the role of the constitution in maintaining the existing power structure and/or preserving democracy
* No final examination

EID 101 : ENGINEERING DESIGN AND PROBLEM SOLVING I -- SPACE CONCEPTS AND GUIDED DESIGN

Required course, lower level.

Key features when taught as regular course:

For graphics part:

* 1 hour of lecture, 1 hour of recitation per week
* Homework problems reviewed in class, with professor at blackboard
* Graphics part of course has single text; no study guides used

For design part:

* 2-hour project meetings weekly with students working in teams of 5-7, for first seven weeks of the course
* Last seven weeks of term, students work on new projects by self or in very small groups

Key features when modified as competence course:

* Same lecture/recitation class structure for graphics part, using same text as before
* Lectures the same for subject matter; attention drawn to competences
* When reviewing homework problems, 3-4 students at the blackboard at the same time, writing out solutions. Students need to be prepared to display solutions.
* Occasionally, the A/V technician videotaped student homework presentations, without advance notice.
* Essay assignment was new.
* Division of course into specific modules, and preparation of study guide which explained exactly what was to be done in class and at home, week by week. Study guide contains some class exercises, a scenario for the term project, topics for group discussions and presentations, and handouts from books other than the main text.
* Entire class worked on one large design project for the entire term -- to design a development plan for a self-sufficient utopian community. Class divided into teams to work on different facets of the problem. Development of coordination among team members is an important part of the course.
* Main class term project required new kinds of information gathering, such as interviews with community leaders, attendance at community board meetings, digging out information on banks and property financing.

EID 140 : ENVIRONMENTAL FUNDAMENTALS   Elective seminar, upper level.

Key features when taught as regular course:

* A single text book
* Forty-five hours of lectures, by the professor.(all class times)
* Regular examination format

Key features when taught as competence course:

* Variety of readings -- three required texts, and supplementary articles
* Thirty-four hours of lectures by the professor, eleven hours of seminars by students (one seminar per student)
* Introduced a study guide, with course modules and weekly assigned readings, technical review assignments, and other unusual assignments.
* Assignments included:
  - Preparation of short videotape on air pollution in New York City and the role of an Air Quality Department, for "delivery to a citizen's committee"
  - Writing interoffice memo on the qualifications to be sought in a prospective commissioner of the Department
  - Preparation of written and oral reports on how a new agency should collect and analyze data -- a small group assignment
  - Collection and comparison of data from New York City agencies on CO and CO_2 levels in 1967 and 1970
  - Preparation of one-hour class presentation on a technical topic of a student's choosing
* Mid-term examination required reading a book about values and engineering, and writing a critical essay.
* Final examination was a full class (enrollment 4 first year, 11 second year) policy report, similar to that required in professional situations. One year was preparation of a policy report recommending whether to require diesel fuel conversion of all New York City taxis. Class responsible for defining problem, collecting data from a number of sources, and for making a comprehensive report, considering technical, economic, social, and political issues.

ESC 161 : LINEAR SYSTEMS

Required of junior Mechanical Engineering Majors

Key features when taught as regular course:

* One text used, and course structure based on text
* All assignments from text book
* Several recommended supplementary books used also

Key features when modified as competence course:

* Developed study guide, with course modules
* More varied reading assignments -- in text and photocopied articles from other books
* Homework assignments from text and/or special assignments
* Occasional laboratory experiments
* Students required to make oral presentation of <u>any</u> problem solution, without advance notice, also possibly have presentation video-taped
* Required project with written report and video presentation

APPENDIX B:

SAMPLE EXCERPTS OF CLASS ASSIGNMENTS, STUDY GUIDES AND ASSESSMENT MANUALS USED IN THE COOPER UNION PROFESSIONAL COMPETENCE DEVELOPMENT PROJECT

SAMPLE: COURSE "INSTRUMENT"
as used in Introduction to Politics Course

Instrument #7

Course Outline Index: II, D - G

Prepare for a 20-minute, videotaped roundtable discussion dealing with the questions:

Is the present constitution reflective of the existing power structure?

Is it an appropriate instrument for maintaining the existing system?

Is this function -- system maintenance -- compatible with the preservation of democracy?

What changes, if any, should be made in the present constitution?

Students will be divided in groups of 5 or 6 and will choose discussion leaders within each group.

The assignment will be evaluated on the following:

PROBLEM-SOLVING: LEVEL 2. Analyze situations new in configuration but similar to known ones in substance. Recognize needs and devise alternative proposals and problem-solving strategies.

COMMUNICATION: LEVEL 1. Demonstrate ability to receive and send information via media presentation, within the context of a standard academic assignment.

VALUE CLARIFICATION. Demonstrate understanding of the philosophical and social basis of the value, democracy.

SAMPLE: STUDY GUIDE COMPONENT
as used in Engineering Drawing Course

What to do

* Read and reflect on what is written in this module the first week of the assignment.

* Study Chapters 7, 8, and 9 in your text book.

* Draw a view of one of the five Platonic solids such that the line of sight is along a main diagonal (i.e., a line joining two opposite corners through the center). Represent the sphere circumscribing the polyhedron. This will be due the second week of the assignment. (See example in appendix for the cube.)

* Construct the five regular "internal" polyhedra according to the method shown in the appendix. (Due the second week.)

* Do the following drawings: 23, 28, 32, 33. (Due the first week.)

Note: Here again, accuracy and neatness are essential. Particularly in the construction of the internal polyhedra, the geometric construction on paper of each cell and the cutting out must be done with all the precision you can muster. Any imprecision here will be multiplied as you put the cells together. Imprecision will translate itself by warped surfaces at best, and, at worst, by the impossibility of fitting the pieces together.

What will be expected

What is expected here is that you develop the ability to see and to represent things from various viewpoints.

Specifically, having studied and done the exercises assigned in this module, you will be expected to be able to execute in the time allocated any of the drawings 23 to 33 with at least a passing grade.

In terms of competences, this corresponds to a performance at Level 2 in Problem-solving and at level 1 in Communication.

For the value clarification, the essential point to notice here is the dependence of the multiplicity of viewpoints on values. If you really know what you are doing when you draw your clip bracket, these are the very questions which you should be addressing: Why do you pick this view rather than another one? What is the purpose of this drawing? Who will use it: the machinist, the draftsman, your supervisor? Is the drawing to be used for machining purposes? For assembly? Or for what? Is any part not shown clearly? May anything be a source of confusion? Does it matter? What are the likely consequences? Etc., etc....

SAMPLE: LEVEL TWO COMMUNICATION ASSESSMENT
as used in Environmental Fundamentals Course

PURPOSE At this second level, the student, in addition to writing well, will be expected to orally communicate with an audience as in the first level. Reasonable notice and preparation time will be included along with his assignments.

METHOD Several categories of assessment will be applied. In one type, the student will prepare a short talk at the audio/visual center, and will replay the tape later for self-assessment. In another instance, the student might be asked to present material to the class. In this case, the assessment will come from both the class and the instructor. In addition, periodic personal conferences will be scheduled. Finally, whenever the student or the instructor deem it necessary that extra help is needed, the student will be directed to the communications clinic for assistance.

CRITERIA The following judgment criteria will be included in level two evaluation:

a. The ability to speak on one's feet (this should include use of minimal notes).

b. The ability to convey one's thoughts clearly (this should include organization of material).

c. The ability to reach one's audience via delivery technique (this should include proper articulation, voice projection, personal apperance, etc).

d. The ability to make use of visual aids (this might include overheads, charts, etc).

FEEDBACK Feedback will be supplied from many sources. In the self-assessment mode, the student will depend on himself for feedback. Whenever the speaking is done in class, both the student's peers and his instructor will supply classroom feedback. In addition, during the student's personal conferences, he will be supplied with feedback by his instructor.

SAMPLE: SELF-ASSESSMENT AND PROFESSOR ASSESSMENT SHEET
as used in Physics Laboratory Reports

Lab Partners:

Experiment No. ____ Name ______________________

Physics 91* (NSF) Name ______________________

SELF-ASSESSMENT GUIDE FOR REPORTS

(This sheet is to be incorporated as the second page of each submitted report. The cover sheet will be the first page.)

The items listed below may be considered either as a checklist to guide you in the preparation of a laboratory report, or as a series of questions that might be asked by the evaluator. Please do NOT fill in the blanks; if any deficiency exists in the final report, the evaluator will comment in the appropriate space. If YOU consult the checklist as you prepare your report, the blank spaces ought to remain blank.

CONTENT

THEORY AND PLAN:
Have you clearly explained what is to be done in the lab? ________
Have you clearly explained how the purpose is accomplished? ________
Is the equipment described diagrammatically and/or verbally? ________

DATA TABLES:
Do your tables have a space for every pertinent observation? ________
Do your tables make provision for quantities to be calculated? ________
Likewise, for uncertainties? ________

GRAPHS: Title? ________ Axes labeled? ________
Units indicated? ____ Scales appropriate? ________

SAMPLE CALCULATIONS:
Are they clearly presented, including uncertainties? ________
Are uncertainties included?________

TABULATION OF RESULTS/DISCUSSION OF RESULTS:
Are your conclusions related to the purpose of the experiment? ________
Are deviations from "standard" results discussed or explained? ________
Are questions asked by the lab-manual answered?________

PRESENTATION

Clean, neat, and legible ____
Sections labeled ____
Diagrams clear and labeled ____
Graphs crisply presented ____
Grammar, spelling, structure ____
Tables ruled and headed ____
Cover sheet completed ____
Folder____

SAMPLE: PROBLEM-SOLVING ASSESSMENT
as used in Guided Design Course

Problem-solving: the ability to recognize a need and act accordingly.

A. This competence involves innovation and is part of the problem-solving process. Based upon limited information given in scenario form, the student must go beyond the symptoms to find out what needs to be solved. This is an extremely important step in the process since little is gained by not addressing the real problem at hand. Again, this competence will be assessed during the first step in the Guided Design process.

B. Level 2 of problem-solving. (It is not expected that students be able to achieve this level here. This step will still serve as an introduction to this competence area which will be developed further throughout the curriculum.)

C. The instrument to be used is the same as described previously; however, some heuristic examples will be provided in the study guide with the intent of sparking the student's imagination.

D. Whether or not the student can recognize the real problem as intended by the instructor and define it clearly.

E. Performance will be in the form of a Goal Statement which constitutes the next step in the Guided Design process.

F. The instructor will judge the Goal Statement and record the results. Of course, if the student proposes a different goal from that of the instructor, there is still the possibility that credit be given, especially for a creative idea that the instructor may have overlooked.

G. Written feedback to individuals.

H. Oral summary of group results to class.

SAMPLE: COMPONENT AND ASSESSMENT
as used in Math Course

Assessment and Competences

We now discuss how the student is to be assessed -- that is, how the student is to be observed and judged. To begin with, a grade will not be a matter of comparing a student to another, but rather a reflection of how well he or she mastered the three competences which follow.

Problem-Solving Competence

The problem-solving skill will be divided into two levels. At the first level the student should be able to formulate a variety of problems, select appropriate approaches for solving them, and generate solutions. For example, the student should be able to set up a minimum/maximum problem to solve a given task and apply the appropriate techniques of differential calculus to arrive at the solution. The student should understand the principles and concepts of Ma 10 and 11 and how they are used to solve a variety of problems in mathematics, engineering and the sciences.

At the second level, the student should demonstrate an ability to select wisely from a list of potential approaches to arrive at a desired solution. One approach might be preferable to another because of time, ease of computation and elegance. At this level, the student should be able to evaluate the process by which a problem was solved, check logical consistency, determine if all the data and conditions have been used and if assumptions are needed.

Communications Competence

Here the student is being judged on his or her ability to receive and send information in a variety of modes -- oral and media presentations, written materials, numerical and graphical representations. This skill will also be divided into two levels. At the first level the student should be capable of communicating effectively in the context of standard academic assignments and tasks. The student should be able to receive information via written and oral materials (textbook, lectures, small group interactions, etc.), to speak clearly and audibly when called upon in class and in small group sessions, to write legibly, grammatically and clearly in examinations and homework assignments, and to recall and use facts and demonstrate comprehension of the material.

At the second level the student should be able to make a good presentation before the class of previously prepared material, such as a particularly elaborate solution or a mathematical concept. The student will be expected to participate in a videotape presentation by his or her small group of a selected UMAP application (described in the study guide). In addition to speaking clearly and audibly and demonstrating comprehension of the material, the student will be judged on such matters as organization, thoroughness and poise.

Value Clarification Competence

In this competence the student will be judged at only one level. The particular approach and attitude selected to solve a given problem reflects, consciously or not, the student's technical and esthetic values. The difference in two solutions to a given problem can be the difference between ironing a handkerchief with an iron or a steam roller. One solution can be "easier" than another in the sense of simplicity, clarity, organization and beauty. Also, one solution can be more "rigorous" than another in the sense of requiring fewer assumptions or unproven tenets.

Evaluation and Feedback

After a period of only two or three weeks, evaluation of students in terms of the three competences will begin, as will feedback in the forms of peer evaluation and instructor evaluation. Small group sessions will offer each student frequent critiques and recommendations from the other members of the group in relatively friendly settings. Stand-up presentations will afford opportunities to receive critiques and recommendations from the student's peers as well as instructor. The student will also receive feedback through periodic personal conferences with the instructor, as well as, of course, from examination returns.

APPENDIX C

STUDENT COURSE EVALUATION FORM USED IN THE COOPER UNION
PROFESSIONAL COMPETENCE DEVELOPMENT PROJECT

Developed by Formative Evaluation Research Associates

COURSE: ______________________________

COURSE EVALUATION

THE COOPER UNION FOR THE ADVANCEMENT OF SCIENCE AND ART

Introduction

As you know, this course is designed to develop professional competences and skills, as well as content expertise. In some ways, this represents a major innovation in undergraduate engineering education. Consequently, we are very interested in your reactions to this course. Not only will your opinions be of interest to the project directors, but you can help to improve this course in the future. Although we ask for your Social Security number, this is strictly for follow-up purposes. All responses are confidential. Your professor will not tabulate this form. No names(s) will ever be revealed, nor will this information affect your grade. In advance, thanks for your help.

1a. Now that the semester is almost over, please reflect on this question, which is similar to one you saw on the first evaluation form. In the space provided from the list below, please identify:

* (asterisk): the competence you feel is your major strength.

- (dash): the competence you feel you developed most this term.

o (dot): the competence you expected to change the most during this term.

(NOTE: You may put all three symbols on one skill or divide them among the three skills, depending on your feelings about these points.)

__________ PROBLEM-SOLVING SKILLS

__________ COMMUNICATION SKILLS

__________ VALUE CLARIFICATION

1b. Other comments regarding your interest in these areas or your ability to develop these competences are welcomed:

2. How well did this course meet your <u>expectations</u> of it?

___Very well ___Well ___Satisfactorily ___Not very well ___Not at all

Why? (please explain):

3. How satisfied were you with your <u>relationship</u> with your teacher?

_____Very Satisfied _____Somewhat Satisfied _____Barely Satisfied _____Not at all Satisfied

Why? (please explain):

4. How satisfied were you with your mastery of the <u>content</u> of this course?

_____Very Satisfied _____Somewhat Satisfied _____Barely Satisfied _____Not at all Satisfied

Why?

5a. How satisfied were you with your mastery of the competence of <u>problem-solving</u>?

_____Very Satisfied _____Somewhat Satisfied _____Barely Satisfied _____Not at all Satisfied

Why?

5b. How satisfied were you with your mastery of the competence of <u>communication skills</u>?

_____Very Satisfied _____Somewhat Satisfied _____Barely Satisfied _____Not at all Satisfied

Why?

5c. How satisfied were you with your mastery of the competence of values clarification?

_____Very Satisfied _____Somewhat Satisfied _____Barely Satisfied _____Not at all Satisfied

Why?

6a. How effective* would you rate the various assessment tools used by your professor?

Please circle the appropriate answer(s).

ASSESSMENT TOOLS	VERY ACCURATE	ACCURATE	RARELY ACCURATE	NOT AT ALL ACCURATE	NOT UTILIZED
Papers	1	2	3	4	5
Tests	1	2	3	4	5
Videotapes	1	2	3	4	5
Speeches/presentations	1	2	3	4	5
Other:	1	2	3	4	5
	1	2	3	4	5

*i.e., "Effective" means the accurate assessment of your skills, competences, and knowledge.

6b. Please check ( ) the method you enjoyed the most.

_____ Papers

_____ Tests

_____ Videotapes

_____ Speeches

_____ Other: ______________________ (specify)

Why? (please explain)

6c. Were you clear as to the criteria used to assess your problem-solving, communications, and/or values-clarification skills:

_____Yes, completely _____Yes, in general _____No, rarely _____Not at all

Please explain your answer:

7. What do you consider the major strengths and weaknesses of this course?

STRENGTHS	WEAKNESSES

8. This section of the questionnaire asks you to reflect on the relationship between your course work at The Cooper Union and certain educational outcomes. Please insert the appropriate number (1-4) in each box, using the following scale and list <u>all</u> your current courses in the blank boxes (top right-side section).

SCALE: 1 = very well 3 = satisfactorily
2 = well 4 = not very well

ALL CURRENT COURSES

MY COURSES ACHIEVED THESE OUTCOMES:						
a. Improved communication abilities, including the skills to read, write, and speak effectively in English within a variety of situations (e.g., reports, generations, interpersonal groups).						
b. Improved interpersonal and organizational abilities including: o helping skills (e.g., listening and understanding others) o leadership skills (e.g., organizing, planning) o organizational skills (e.g., work effectively in bureaucratic organizations).						
c. Improved thinking abilities and problem-solving including: o number skills (e.g., computing) o intellectual inquiry skills (e.g., information gathering, ordering) o analytical thinking skills (e.g., problem-solving) o evaluation skills (e.g., testing ideas).						
d. Improved creative abilities including: o innovative skills (e.g., inventing, developing alternative interpretation of events) o artistic abilities (i.e., musical, dance, or dramatic performing).						
e. Personal growth outcomes including: o stimulating curiosity and desire to learn more about the subject o introducing significant ideas o engaging and challenging ideas and assumptions.						
f. Clarified values including: o increased understanding of values o their application to engineering situations o their relevance to various ethnic groups and their cultures.						

9. What two improvements would you recommend for this course?

IMPROVEMENT #1	IMPROVEMENT # 2

10. Thinking about your skills, knowledge, and interests, do you feel as though you have significantly changed this term?

_____ Yes, I have changed a lot   _____ Yes, I have changed a bit   _____ No, I haven't changed much

If yes, then how?

11. Other comments:

Thanks for your help! Please see your professor later next term if you are interested in seeing a summary of this survey.